

North Atlantic warming: patterns of long-term trend and multidecadal variability

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3.1 Interactions between the Arctic and the Earth System, State of the Arctic, Miami, FL, March 2010



Main Results

- The recent warming over the North Atlantic is linked to both long-term (including anthropogenic and natural) climate change and multidecadal variability (MDV, *50– 80 years).
- There is a warming trend of $0.031 \pm 0.006^\circ\text{C}/\text{decade}$ in the upper 2,000 m North Atlantic over the last 80 years of the 20th century.
- Multidecadal variability accounts for ~60% of North Atlantic warming since 1970.

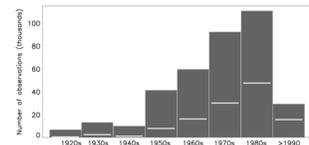
Motivation, Methods, and Background

Goals

- This study assesses the relative contribution of the long-term trend and variability of North Atlantic warming using EOF analysis of deep-ocean and near-surface observations.

Data and Methods

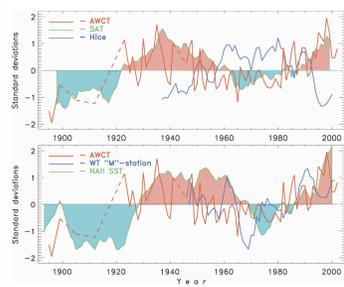
Fig. 1 Number of observational stations used for analysis. White horizontal lines within the grey bars show the number of observations available for analysis of the deeper Atlantic Ocean (1,000 m)



Number of oceanographic observations, line shows those > 1000m

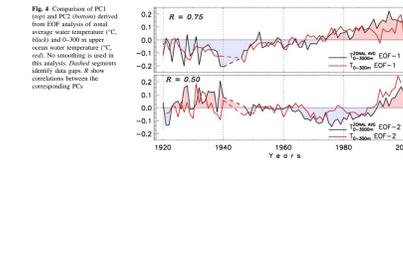
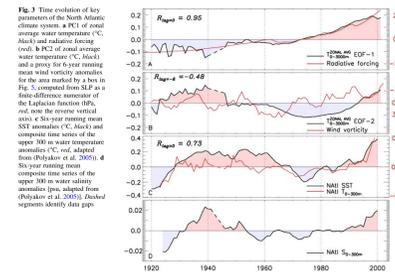
- Observed Data
 - World Ocean Database [Boyer et al. 2006] and WOCE data from 1990-1997
- Analysis
 - Zonal annual average (0-2000 m) N. Atlantic, Construct EOF of correlation matrix, regressions, Model Data: IPCC 2007 20th century simulations

Striking Similarity Between Climate Variations in the Arctic/North Atlantic climate system

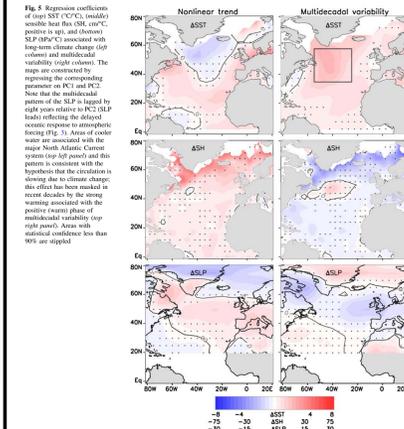


Arctic: SAT, Atlantic Water & Kara Sea ice thickness
 Atlantic: SST & SST OWS M
 Changes in supply of Labrador Sea water as part of MOC
 Cooler MDV Period, 1965-78
 Warmer MDV Period, 1988-2001
 Polyakov et al. [2005]

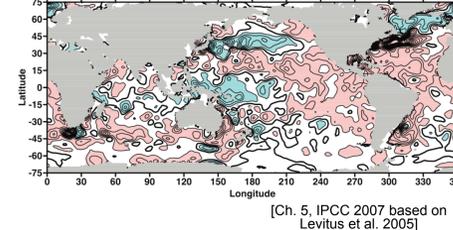
PC1 compares favorably with radiative forcing & PC2 matches N. Atlantic multi-decadal variability



Regression patterns over N. Atlantic differ for PCs



Similar to linear trend in heat content - spatial variability in N. Atlantic



1955-2003 ocean heat content trend (Wm^{-2}) for the 0-700 m layer. C.I. is 0.25 Wm^{-2} .

In general, GCMs simulate patterns of trends better than patterns of MDV

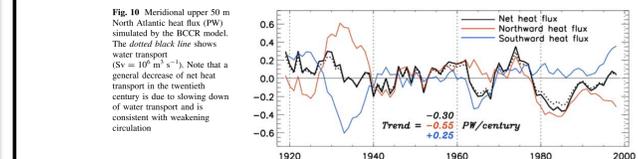
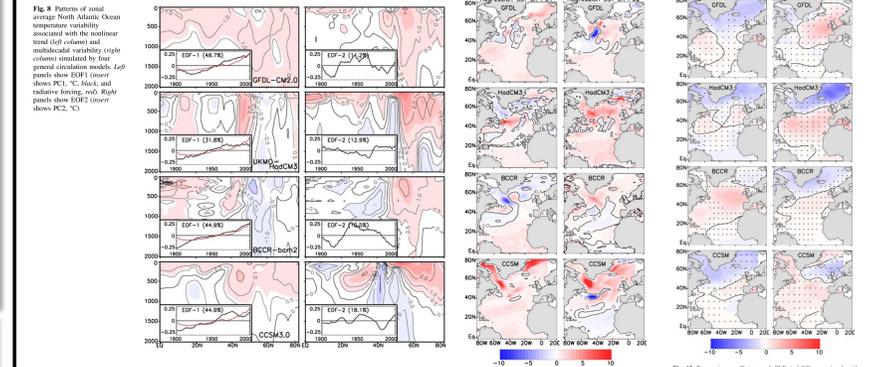
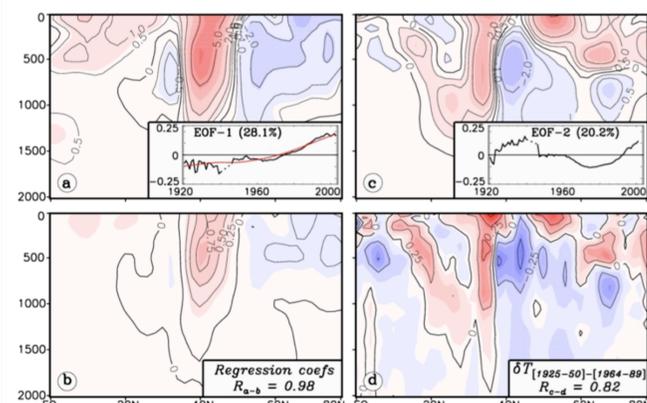


Fig. 10 Meridional upper 50 m North Atlantic heat flux (PW) simulated by the BCCR model. The dotted black line shows water transport ($\text{Sv} = 10^6 \text{ m}^3 \text{ s}^{-1}$). Note that a general decrease of net heat transport in the twentieth century is due to slowing down of water transport and is consistent with weakening circulation.

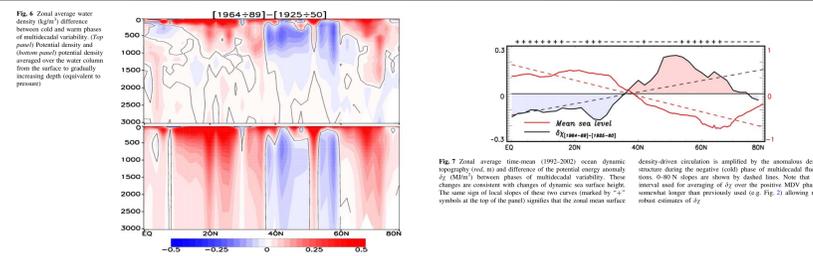
EOF1 & EOF2 of North Atlantic Ocean Temperature 0-2000m Displays Trend and MDV



- Data was smoothed above (same answer no smoothing)
- Significantly separated modes [North et al 1982]
- For more details on sensitivity of the answer to averaging, smoothing, errors, data gaps, etc. see paper Appendix of Polyakov et al. 2009.
- Red Line - Net radiative forcing from NASA GISS
- EOFs of top 300m ocean heat content yields similar PCs

Fig. 2 Patterns of zonal average North Atlantic Ocean temperature variability associated with the nonlinear trend (left column) and multidecadal variability (right column). a) EOF-1 (insert shows PC1, $^\circ\text{C}$, black, and radiative forcing, red); for comparison, b) regressions of zonal average water temperature on the radiative forcing time series ($10^{-1}^\circ\text{C}/\text{ppm}$); c) EOF-2 (insert shows PC2, $^\circ\text{C}$); for comparison, d) zonal average water temperature difference between positive and negative phases [(1925–1950)–(1964–1989)] of multi-decadal variability ($^\circ\text{C}$) (detrending of the data is applied using nonlinear trends defined by the radiative forcing time series; weak three-point four-passes smoothing based on the Laplacian operator is applied). R indicates pattern correlations between the corresponding panels.

During warm MDV phase, the MOC is enhanced



References

- Polyakov, I.V., V. A. Alexeev, U.S. Bhatt, E.V. Polyakova, and X. Zhang, 2010: North Atlantic warming: Patterns of long-term trend and multidecadal variability, Climate Dynamics, doi:10.1007/s00382-008-0522-3.

Acknowledgements

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Summary

- Recent warming over the North Atlantic is linked to both anthropogenic climate change and MDV (~50-80 years).
- The MDV has basin-scale sea surface temperature anomalies accounting for ~60% of North Atlantic warming since 1970.
- In contrast, the overall long-term warming trend exhibits a pattern of cooling in regions associated with major northward heat transports, consistent with a slowdown of the North Atlantic circulation.
- The North Atlantic cooling has been masked in recent decades by warming during the positive phase of MDV.
- Surprising Stuff: Ocean response to GHGs, Caveat: Trend and MDV treated separately

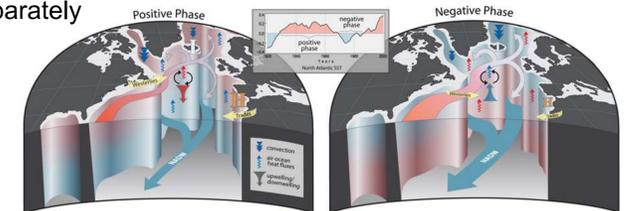


Fig. 13 Schematic depicting the two states of multidecadal variability in the North Atlantic is based upon previous studies in conjunction with current findings (see Sect. 4 for details)